



Does Fermilab Have a Future?

The United States's last particle physics lab finds itself in turmoil, with its current experiments soon to wind down and nothing under construction to replace them. Physicists wonder whether the lab—and particle physics in the United States—will survive

BATAVIA, ILLINOIS—Like a magnet, particle physics drew David Mason when he was an undergraduate. “I was initially attracted by all the cool toys we play with,” says the postdoc here at Fermi National Accelerator Laboratory (Fermilab). “Basically, everything we use we have to construct for ourselves because it’s never been thought of before.” Mason, 37, first worked in a lab as an undergrad at the University of Oregon, Eugene. In 1996, he came to Fermilab, whose bucolic 2750-hectare campus preserves a patch of quiet in the suburban sprawl 60 kilometers west of Chicago, as an Oregon graduate student to study particles called neutrinos. After finishing his doctorate 2 years ago, he signed on to collaborate on an experiment that will be done in Europe.

Now, Mason finds himself spending his savings to keep his young family afloat.

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Podcast interview
with the author of
this article.

Rocked by budget cuts late last year, Fermilab will soon lay off about 140 of 1950 staff members (*Science*, 16 May, p. 858). In February, the lab instituted a rolling furlough that, until year’s end, requires employees like Mason to take 1 week every 2 months as unpaid leave. The 25% cut in every other paycheck hurts, says Mason, whose wife stays home with his 2-year-old son.

Perhaps more troubling, the budget crunch leaves the future of the 40-year-old lab, the United States’s last dedicated particle physics lab, uncertain at best. Fermilab’s current experiments will wind down early next decade, and the U.S. Congress cut funding for the projects meant to replace them (*Science*, 11 January, p. 142). The action is shifting to Europe and Japan, and Mason, who says moving abroad is probably out of the question, wonders how long he can stick with the

field. “On one hand, this is what I’ve spent years of my life preparing for,” he says. “On the other hand, my family has to eat.”

American particle physics stands at a crossroads. Since the invention of the cyclotron in 1929, the United States has led the quest to bust matter into bits and see what the universe is made of. The science is more exciting than it has been in decades, researchers say. Fermilab’s particle smasher, the 6.3-kilometer-long circular Tevatron collider, is cranking out copious data that could reveal the long-sought Higgs boson, the missing link in the “standard model” of the known particles. This summer, the European particle physics lab, CERN, near Geneva, Switzerland, will turn on its Large Hadron Collider (LHC), a 27-kilometer ring that could blast out scads of new particles and recreate conditions of the big bang. The United States has 1300 researchers working on the LHC, more than any other country.

Twilight? The denizens of Fermilab's iconic Wilson Hall worry for the lab's future.

But the United States's position in particle physics has been slipping, and this year the decline has snowballed into a crisis. In the past 3 months, U.S. researchers have shuttered colliders at Cornell University and the Stanford Linear Accelerator Center in Menlo Park, California. Only the 25-year-old Tevatron remains, and it will shut off in 2010. Fermilab's smaller experiments will end at about the same time. In this country, the cupboard is bare, and physicists have only unapproved plans with which to restock it.

The immediate cause of the turmoil at Fermilab is the last-minute budget Congress passed in December. It trimmed Fermilab's budget to \$320 million this year from \$342 million in 2007, \$52 million less than requested by the U.S. Department of Energy (DOE), which owns the lab. Congress zeroed out \$36 million for a proposed neutrino experiment called NOvA; slashed \$14 million for work on the proposed multibillion-dollar International Linear Collider (ILC), which American physicists hope someday to build at the lab; and clipped \$18 million for research on superconducting accelerator technology. "You took all the things that the lab was working toward for a future facility and you lopped them off," says Fermilab Director Piermaria Oddone. "When you do that, you're pointing the laboratory straight for the rocks."

The roots of the problem reach further back. Knowing that the LHC would eclipse the Tevatron, many U.S. physicists and some DOE officials have pushed to start building the ILC at the lab as early as 2016. In their haste, they scrapped smaller projects that otherwise might have protected Fermilab from cost cutters looking for vulnerable research and development expenditures. Or so others say. "It's pretty clear that there was a plan at DOE to clear the decks for the ILC, and a number of us saw that this was incredibly risky," says Sheldon Stone of Syracuse University in New York, who calls the current jam "predictable."



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—FLORENCIA CANELLI,
FERMILAB

THE ONE AND ONLY			
Major Experiments Built at Fermilab Since 1999			
MINOS	Studies neutrinos	\$170 million	Completed in 2005
Major Experiments Canceled at Fermilab Since 1999			
Proton Driver	Various studies	~\$1 billion	Canceled 2006
BTeV	To study B mesons	\$200 million	Canceled 2005
CKM	To study K mesons	\$100 million	Cancelled 2003
KAMI	To study K mesons	>\$50 million	Cancelled 2001

Fermilab is not giving up. To secure their future through the next decade, researchers have proposed a relatively modest billion-dollar proton accelerator, dubbed Project X, to feed neutrino studies and other smaller scale experiments. The stakes are high: If all the accelerators are overseas, U.S. particle physics may simply die, researchers say. "Five years down the road, Congress may look at it and say, 'If there's nothing here, why are we funding this at all?'" says Robert Harr of Wayne State University in Detroit, Michigan. The odds may be long: DOE has completed just one major project at Fermilab in 9 years.

The ILC: A gamble that didn't pay

On 19 February 2006, William Foster penned an open letter to his colleagues. Foster had worked at Fermilab for 22 years, the last five as head of a project that, he thought, would provide the lab with a decade of research to do. Dubbed the Proton Driver, the billion-dollar linear accelerator would have pumped out protons that would crash into targets to generate neutrinos and particles called muons, K mesons, and D mesons for experiments.

But weeks earlier, officials from DOE's Office of Science decided that they would not put the project up for the first of five "critical decision" reviews that any DOE project must pass as it wends its way from idea to facility. The reason for DOE's refusal, Foster wrote, was that the Proton Driver, the concept for which had been proposed by others as early as 1994, would interfere with efforts to get the ILC built as quickly as possible. "This position apparently applies not only to

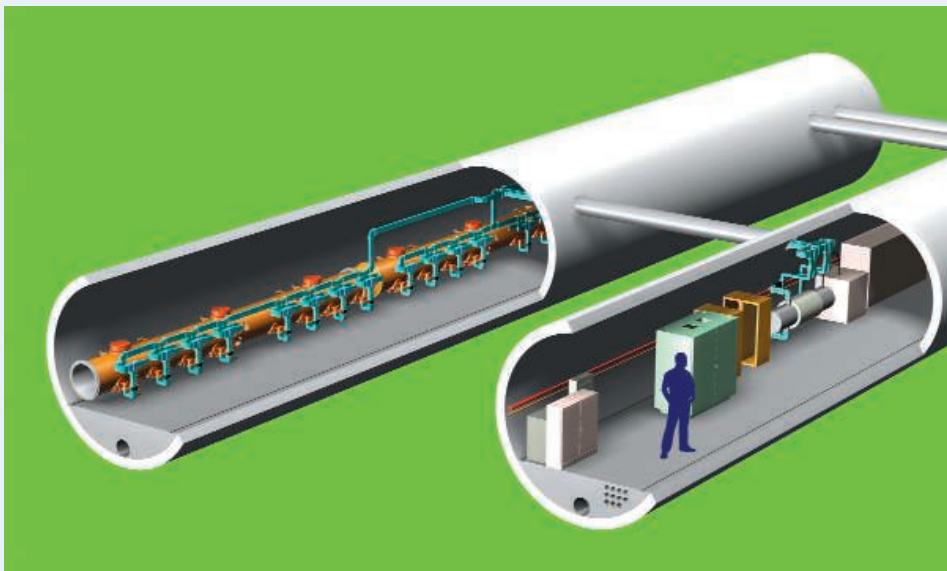
the Proton Driver, but to any intermediate-scale projects which might provide any alternate or interim future for U.S. [high-energy physics] at a cost significantly less than the [approximately] \$10 billion estimated cost of the ILC," Foster wrote. "I fear that this approach is likely to end very badly. ..."

Foster quit the project, the lab, and the field. "The Proton Driver represented my last best effort for Fermilab," Foster says. "And when it was clear that it wouldn't go through, I wanted to try something else where I could be more successful." That something else was politics: In March, Foster won a seat in the U.S. House of Representatives (*Science*, 14 March, p. 1470).

Numerous factors put Fermilab in its riches-to-rags predicament. For more than a decade, the DOE's high-energy physics budget failed to keep pace with inflation; this year it fell 8.5% to \$688 million, from \$752 million in 2007. In 2001, after a major upgrade, the Tevatron performed so poorly that the lab had to throw all it had at the problem (*Science*, 8 February 2002, p. 942). Plainly put, in the past 2 decades, particle physics has produced few of the major discoveries that thrill the public and secure generous funding.

However, many Fermilab researchers argue that the lab is in trouble because, following the lead of advisory panels stacked with ILC supporters, DOE officials have sacrificed modest experiments that the department can afford for a chance at a dream machine that may never come. "We ended up in an ILC-or-bust mode," says Stephen Holmes, Fermilab's associate director for accelerators.

In the past decade, physicists at Fermilab have proposed several hundred-million-dollar experiments that would have searched for new physics by studying the decays of familiar particles in great detail (see table, above). For example, the Tevatron feeds two particle detectors, named CDF and D0, that are searching for the Higgs boson and other new particles. The proposed BTeV detector would have studied well-known particles called B mesons, which the Tevatron produces in spades. The \$200 million effort was



Only longer. An artist's conception of the International Linear Collider, which many physicists say is the future of the field.

U.S. Department of Energy (DOE), warned that it could take until 2025 or later to get the go-ahead for the machine (*Science*, 2 March 2007, p. 1203).

Then in December, the U.K.'s Science and Technology Facilities Council announced that Britain was pulling out of the project entirely, saying it could "not see a practicable path towards the realization of this facility" (*Science*, 21 December 2007, p. 1851). Two weeks later, a quarter of the way into the 2008 fiscal year, Congress cut funding for ILC research and development from a requested \$60 million to \$15 million, stopping work in the United States for the year (*Science*, 11 January, p. 142).

Still, physicists in Europe and Asia continue to soldier on and make progress, Barish says.

And Spain and India have recently joined the effort. What has really suffered, Barish says, are the chances that the machine will be built in the United States, at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. "The most likely place that a machine like this will be built is CERN," Barish says. "It's hard to see a scenario that would bring it to Fermilab at this point."

The United States's prospects for hosting the machine suffered not so much because of the cuts to ILC development but more because of cuts to the U.S. contribution to the international fusion experiment, ITER, which will be built in Cadarache, France. Congress zeroed out the \$149 million that the United States was supposed to contribute this year, leaving the six other ITER partners in the lurch. "At the moment, the U.S. is not a reliable partner for long-term projects, with the obvious consequence that few people think the U.S. is a probable candidate" for hosting the ILC, says Albrecht Wagner, head of the German Electron Synchrotron Laboratory (DESY) in Hamburg and chair of the International Committee for Future Accelerators.

The United States is not giving up on hopes for landing the ILC, however. "There was never—never—a suggestion in my comments or my actions that we were somehow moving away from the ILC," Orbach told *Science* in an interview in January. DOE has requested \$35 million for ILC research and development in 2009. However, observers say Congress is likely to continue with the present budget until a new president takes office in January 2009, at which point the United States's role in the ILC will lie in the hands of the next Administration.

—A.C

Whither the International Linear Collider?

Efforts to develop the International Linear Collider (ILC), a 40-kilometer-long, straight-shot particle smasher, have taken some thumps in the past 16 months. But like a seasoned pugilist, the ILC has rolled with the blows, project leaders say. "We've been slowed down," says Barry Barish, a physicist at the California Institute of Technology in Pasadena, who leads the ILC Global Design Effort (GDE). Still, he says, "in terms of the threat of it being turned off, I don't think there's much chance of that."

Physicists generally agree that the ILC or something like it represents the future of particle physics. This summer, the European lab, CERN, near Geneva, Switzerland, will turn on the Large Hadron Collider (LHC), which could cough up a slew of new particles and perhaps reveal new dimensions of space. The LHC will fire protons into protons, each of which is a knot of particles called quarks and gluons, so it will produce extremely messy collisions. The ILC would collide indivisible electrons and positrons and produce cleaner collisions, which should allow researchers to study in detail the new particles glimpsed by the LHC.

The ILC's troubles began in February 2007, after the GDE released a cost estimate for the machine (*Science*, 9 February 2007, p. 746). It set the "value" of the ILC at \$6.7 billion, not including contingency or inflation during planning and construction. Adding those factors meant that, if the United States hosted the ILC and paid for half of it, its share would total \$7.5 billion. Two weeks later, Raymond Orbach, undersecretary for science at the

canceled in 2005, just as physicists expected the go-ahead for construction. Since 1999, only the MINOS neutrino experiment, which shoots a beam of the elusive particles to a detector in the Soudan Mine in Minnesota, has made it to completion.

Some physicists say it's unfair to blame the ILC for the demise of smaller experiments. In tight budgets, those projects simply weren't worth the costs, they say. For example, BTeV would have required running the Tevatron into the middle of the next decade at a cost of \$40 million per year. "I don't think that anyone can say that BTeV was canceled because of the ILC," says Barry Barish, a physicist at

the California Institute of Technology in Pasadena and leader of the ILC Global Design Effort.

But Raymond Orbach, DOE undersecretary for science, who declined to be interviewed for this article, has indicated in the past that DOE was foregoing smaller projects in favor of the ILC. "There is a fear, and the fear is well-grounded, that we may be sacrificing a lot and that [the ILC] may not come to pass," Orbach told *Science* in a June 2006 interview. "But if we don't take the risk, then we won't have the ILC on shore. ... I want it here, and I want the United States to maintain its leadership in this area, and it's the only way

I know how to do it."

Orbach struck a more cautious tone 8 months later. On 8 February 2007, physicists working on the ILC design released a cost estimate that indicated that if the machine were built in the United States, it would cost upward of \$10 billion, of which the nation's share would be roughly \$7.5 billion (*Science*, 9 February 2007, p. 746). Two weeks later, Orbach told researchers on DOE's High Energy Physics Advisory Panel that the ILC probably could not be built until the middle of the 2020s and asked for smaller projects that the United States could pursue in the meantime (*Science*, 2 March 2007, p. 1203).

Orbach's warning suddenly presented Fermilab physicists with a gap of 15 years or more without an accelerator project. And with nothing beyond the planning stage, many physicists say, the lab became an easy target for congressional budget cutters who had to shear \$22 billion from the 2008 budget to avoid a veto by President George W. Bush.

Project X: Too little, too late?

Now Fermilab researchers have come up with a plan to restore their future. To some measure, lab leaders hope to take up where they left off before this year's crisis. Congress did not cancel the NOVA neutrino experiment, notes Oddone, and physicists hope to resume work on it. Similarly, DOE has requested \$35 million for ILC work in 2009. But most say that, if it is to survive, Fermilab needs a new accelerator project, and getting one may be difficult because the United States's particle physics community has painted itself into a corner, says Joel Butler, a 28-year veteran of Fermilab. "The things we can do are deemed not grandiose enough, and the things that are grandiose enough we can't afford," he says.

Fermilab hopes to solve that paradox with Project X, the conceptual son of the Proton Driver. Similar to the Proton Driver, Project X would consist of a superconducting linear accelerator measuring 700 meters long. Like Proton Driver, it would produce intense beams of protons that could be used to generate neutrinos and other familiar particles. But unlike the Proton Driver, the guts of Project X—the "cavities" through which particles surf on electromagnetic waves—would be more like those in the ILC, says Young-Kee Kim, deputy director at the lab. "The technology is aligned, so any progress we make with Project X will help us with our efforts to host the ILC," she says.

Fermilab hopes to have Project X up and running by 2016, but securing it is not a slam dunk. Many physicists question whether the menu of experiments it would support—precision studies of muons, K mesons, and neutrinos—is hearty enough to justify the expense and sustain the lab. "Thus far, I haven't seen anybody stand up and make the case that the physics that can be done with Project X is as important as building Project X" for the sake of the accelerator program, says Peter Cooper, a physicist at Fermilab. Kim says that everyone to whom she's presented the science case seems convinced.

Project X also has competition. Japanese physicists will fire up their own proton source, the Japan Proton Accelerator Research Complex (J-PARC), this year. It will pursue much of the same physics as

Project X. At least in its first incarnation, J-PARC will produce a beam only half as intense as Project X's. But researchers already plan to upgrade the facility, and Japanese scientists will enjoy a head start of at least 8 years over their Fermilab rivals.

If Project X is going to help, then lab and DOE officials will have to hustle it along. The Tevatron will shut down in just over 2 years, and the accelerators that feed it and the current MINOS neutrino experiment probably won't run much longer. And if the lab goes too long without a working accelerator, it will likely lose the people it needs to build a new one, says Fermilab accelerator boss Holmes. "If you're not operating an accelerator, then you're not going to be able to design and construct a future facility," he says.

Fermilab is hoping to get DOE's preliminary okay in 2009 and start construction in 2012. If nothing is in the works by the time the Tevatron shuts down, then Fermilab will likely cut another 10% to 15% of its staff, Oddone says. Fermilab's Butler warns that, having shelved the Proton Driver once, physicists and DOE may have a tough time selling Congress on a similar project and the experiments it can do. "It's going to be difficult to say that the things that we said weren't that important are now the most important things," Butler says.

The no longer unthinkable

If Project X does not come to fruition, Fermilab won't vanish as soon as the Tevatron shuts down. It will still be the national headquarters for the 630 physicists from the United States who are working on CMS, one of four gargantuan particle detectors at CERN that will be fed by the LHC. The lab is also broadening its mission into astrophysics and cosmology. For example, Fermilab is one of 25 institutions in the Sloan Digital Sky Survey, which since 1998 has used a 2.5-meter telescope on Apache Point, New Mexico, to map 1/5 of the sky. Fermilab also leads the proposed Dark Energy Survey, which would use the 4-meter Blanco Telescope at Cerro Tololo in Chile to probe the bizarre dark energy that is accelerating the expansion of the universe.

But such efforts cannot sustain the lab at its present size. What's more, if Fermilab has no operating accelerator to anchor it, these other activities could be moved to other institutions, researchers worry. "The worst [possible outcome] is that we get shut down," says Fermilab physicist Stephen Pordes, "and the question is, do we get shut down quickly or slowly?"

Still, there are rays of hope for the lab, and Florencia Canelli is one of them. One of Fermilab's best and brightest, the 35-year-old Argentinean holds a Wilson Fellowship—the equivalent of a tenure-track professorship at a university—and has been working at the lab since 1997, when she was a grad student at the Uni-

versity of Rochester, New York. She and her husband, a postdoc from Ohio State University in Columbus, both work on the CDF particle detector, which is fed by the Tevatron. They have fielded offers of dual professorships from three different universities. But Canelli has just decided to stay, taking a joint position with the lab and the University of Chicago, and her husband is taking a staff position at the lab. The two want to devote themselves full-time to exploiting the Tevatron data and gearing up for the LHC, she says.

Their decision marks a small victory not only for Fermilab but also for the U.S. program. Canelli has Italian citizenship, and her husband holds a passport from the United

Kingdom; in principle, they could take off for Europe. But the United States offers opportunities that Europe does not, Canelli says, such as the chance for anyone with talent to climb to the top. "It's a good thing about the U.S.," she says. "I haven't heard of a lot of non-Italians getting a position in Italy or a lot of non-French people getting positions in France."

Canelli says she remains optimistic that the United States won't drop out of the most fundamental physics. "What is matter made of? How does the universe work?" she says. "We will always have these questions. The only question is, is this country going to be involved in getting the answers." Right now, the answer is a definite maybe.

—ADRIAN CHO



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